Preliminary studies of the production of a single Z^0 in a fusion process

$\mu^+\mu^- \rightarrow \nu_\mu \bar{\nu}_\mu Z^0$

using ILCroot

Vito Di Benedetto

INFN Lecce and Università del Salento

Muon Collider Physics and Detector Meeting

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Fermilab

Outline

- **Physics motivation**
- **ILCroot Offline Framework**
- **Detector baseline**
- **Results ...**
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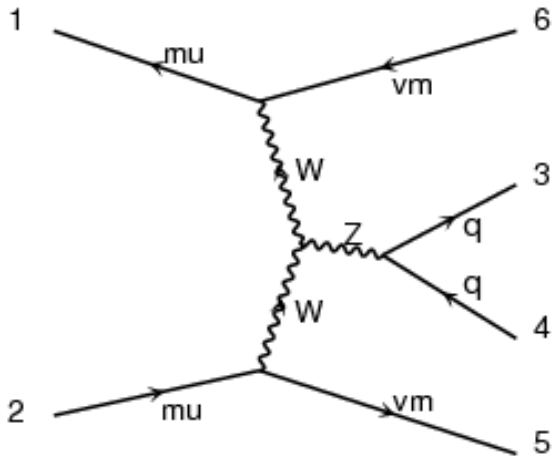
- **Conclusions**

Physics motivation



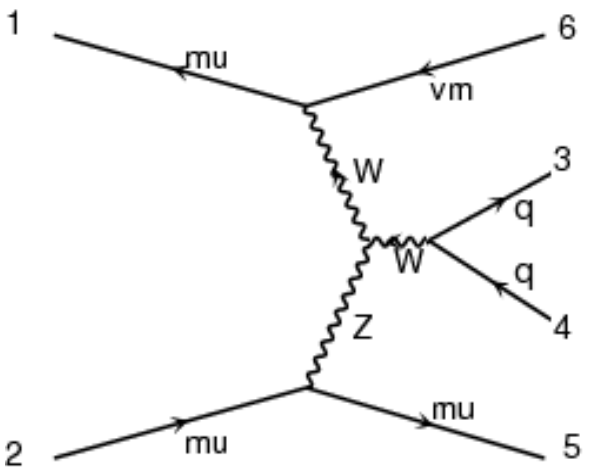
$\mu^+\mu^- \rightarrow \nu_\mu \bar{\nu}_\mu Z^0$ @1.5TeV

↳ jet, jet

Jet's are originated by light quarks (u,d,s)

- **Reconstruct Z^0 mass by jets**
- **Stress calorimeter energy resolution**
- **Tracker performances**

Physics motivation



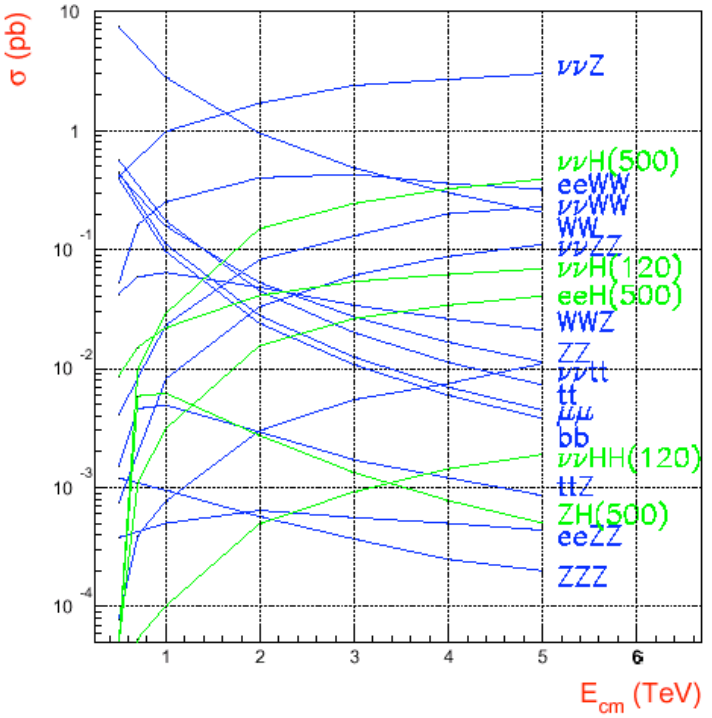
$\mu^+\mu^- \rightarrow \bar{\nu}_\mu W^+\mu^-$

$\hookrightarrow$ jet, jet

- **Reconstruct W^+ mass from jets**
- **In case μ^- isn't tagged, W^+ in this channel can mimic a Z^0**
- **Stress calorimeter energy resolution**
- **Tracker performances**

Physics environment

- **$\sigma(\mu^+\mu^- \to \nu_\mu \bar{\nu}_\mu Z^0) = 4.1089$ pb**
- **μC Luminosity @1.5TeV = $0.8 \times 10^{34} cm^{-2} s^{-1}$**
- **I simulated 9900 events (It is ~3.5 days of data taking)**



ILCroot: **root I**nfrastructure for **L**arge **C**ollider

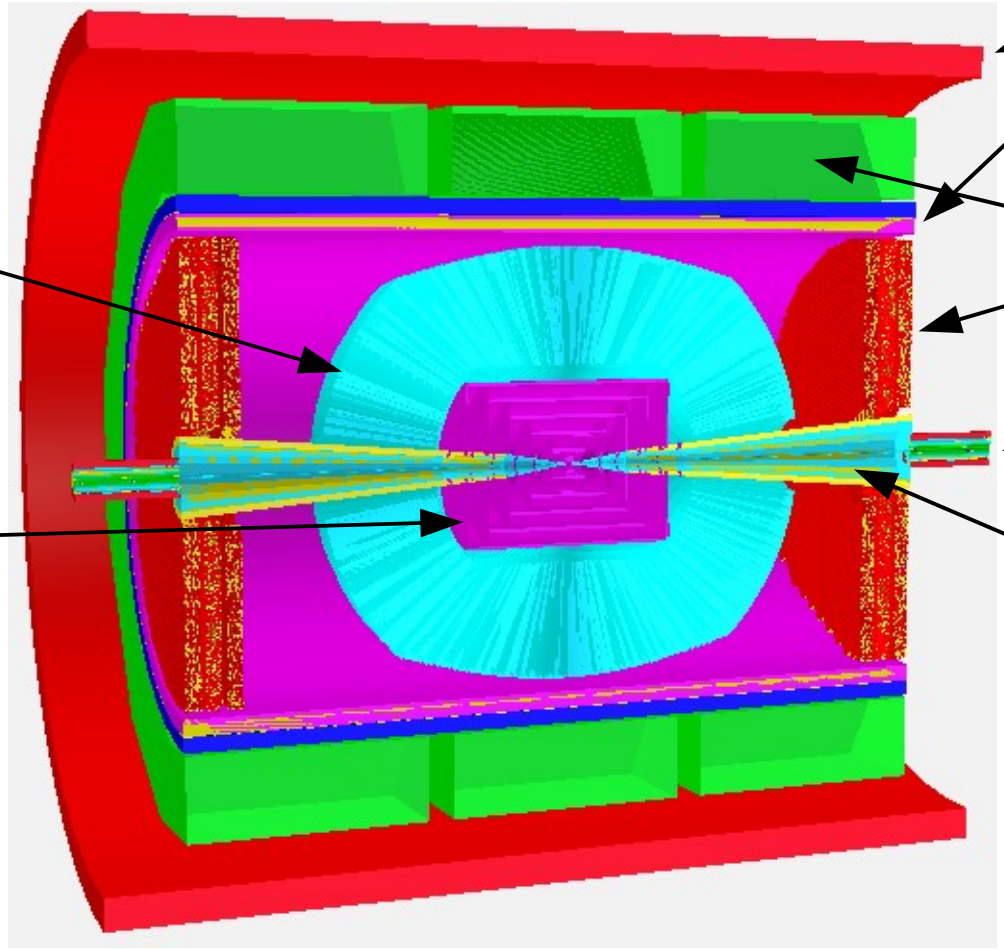
- Software architecture based on ROOT, VMC & Aliroot
- Uses ROOT as infrastructure

  All ROOT tools are available (I/O, graphics, PROOF, data structure, etc)

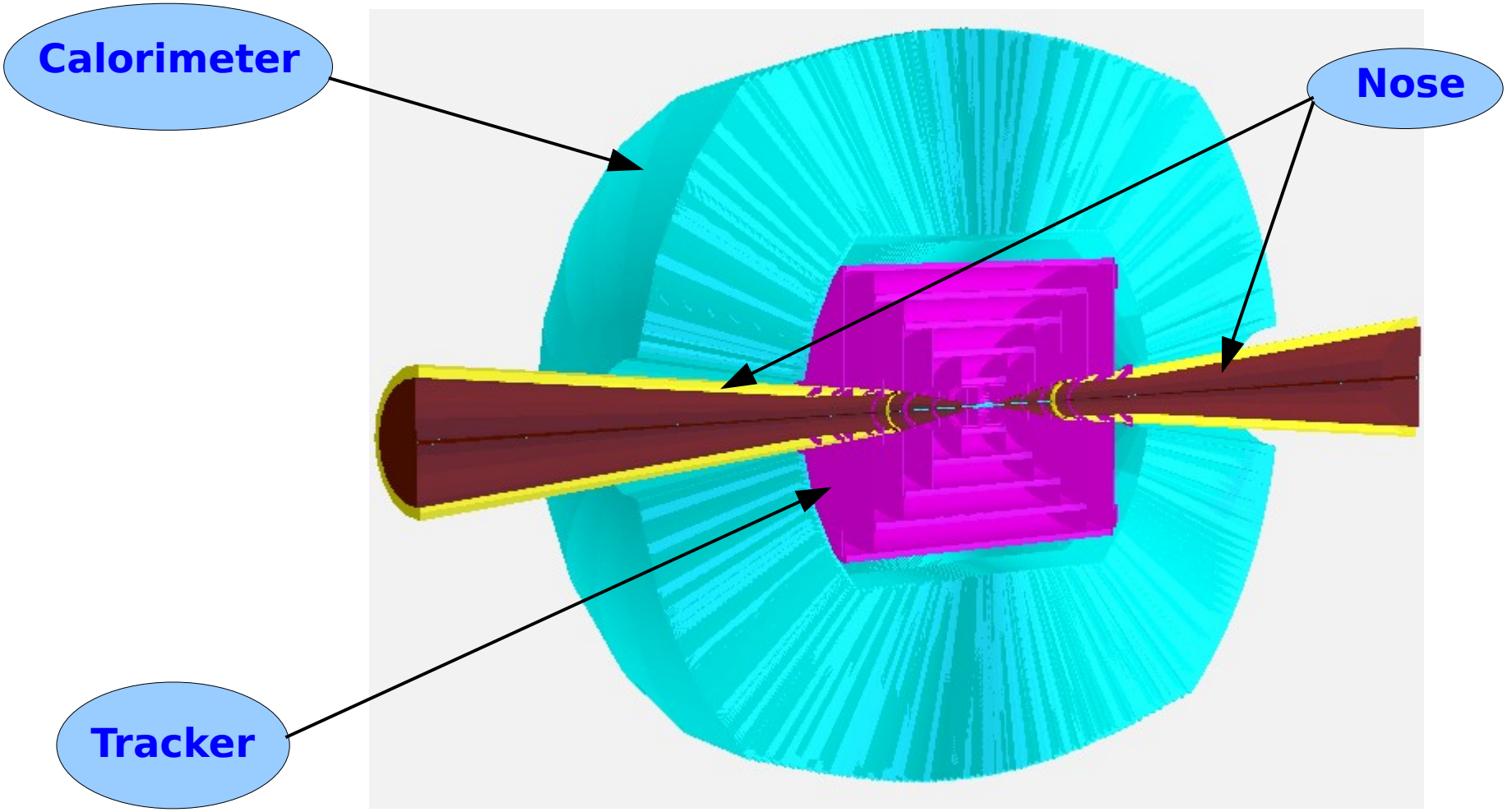
  Extremely large community of users/developers
- Include an interface to read MARS output to handle the MuonCollider background
- Single framework, from generation to reconstruction through simulation. Don't forget analysis!!!
- It is Publicly available at FNAL on ILCSIM since 2006

All the studies presented are performed by ILCRoot

Detector baseline



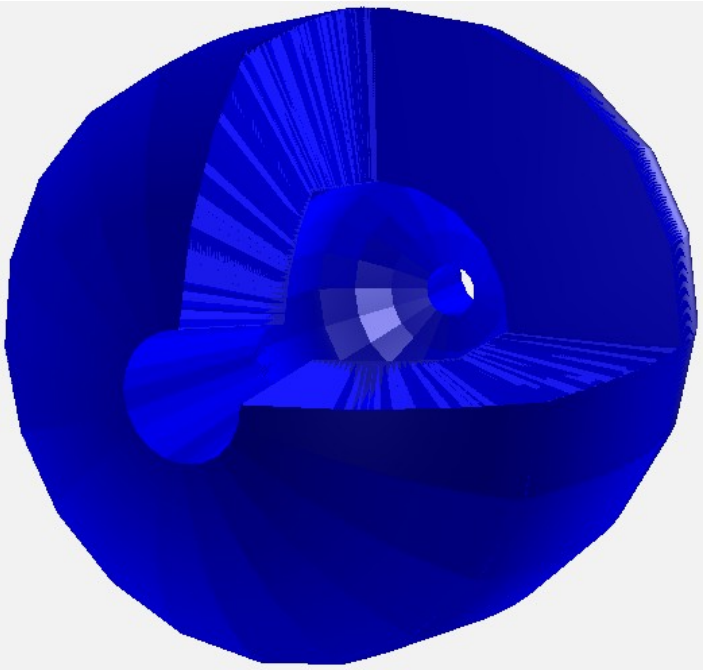
Detector baseline zoom

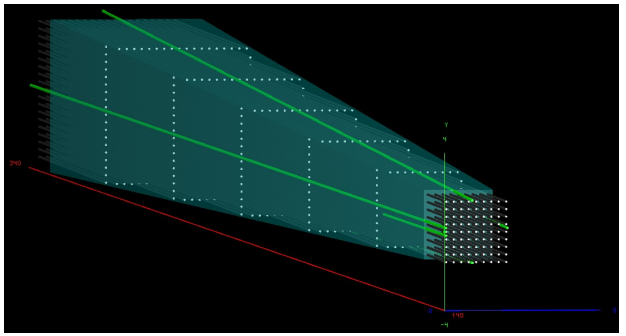


Detector baseline

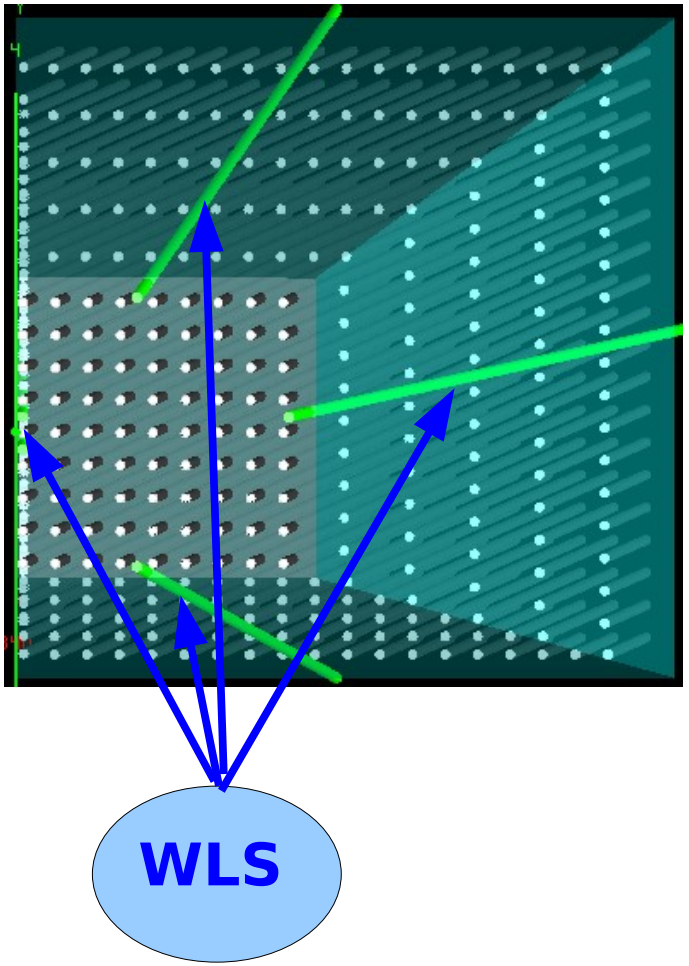
ADRIANO Calorimeter

- Lead glass + scintillating fibers
- ~1.4° tower aperture angle
- 180 cm depth
- ~ 7.5 λ_{int} depth
- >100 X_0 depth
- Fully projective geometry
- Azimuth coverage
  down to ~8.4° (Nose)
- Barrel: 16384 towers
- Endcaps: 5544 towers



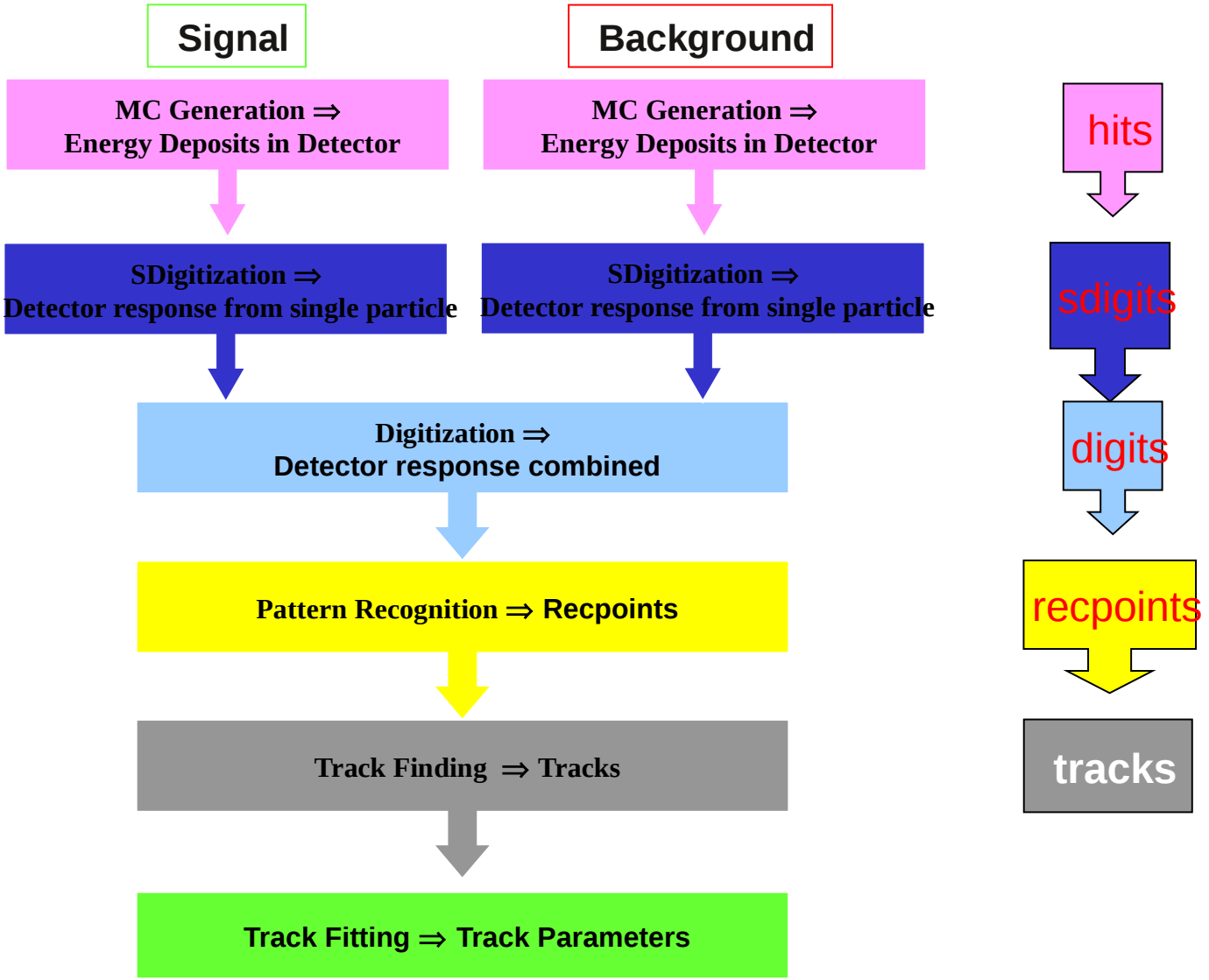


Detector baseline

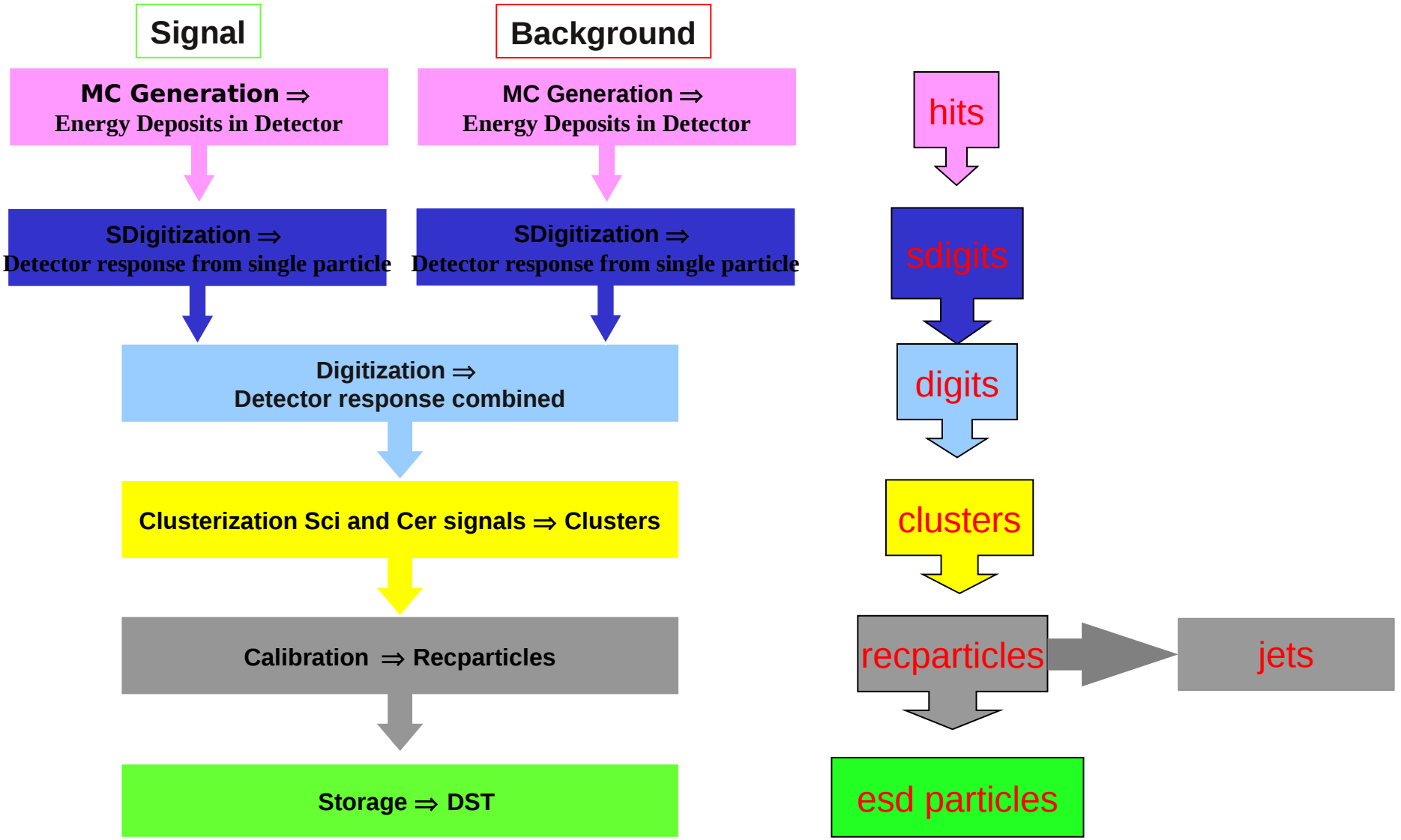


- **WLS's collect Cerenkov photons generated in lead glass (front and back readout)**
- **Scint fibers generate and collect scintillating photons (front and back readout for fibers in the core of the tower; only back readout for the other fibers)**
- **Simulation include:**
  - **SiPM with ENF=1.016**
  - **Fiber non-uniformiti response = 0.8% (scaled from CHORUS)**
  - **Threshold = 3 p.e. (SiPM dark current< 50 kHz)**
  - **ADC with 14 bits**
  - **Gaussian noise with σ= 1 p.e.**

Simulation steps in ILCroot: Tracking system



Simulation steps in ILCroot: Calorimeter system

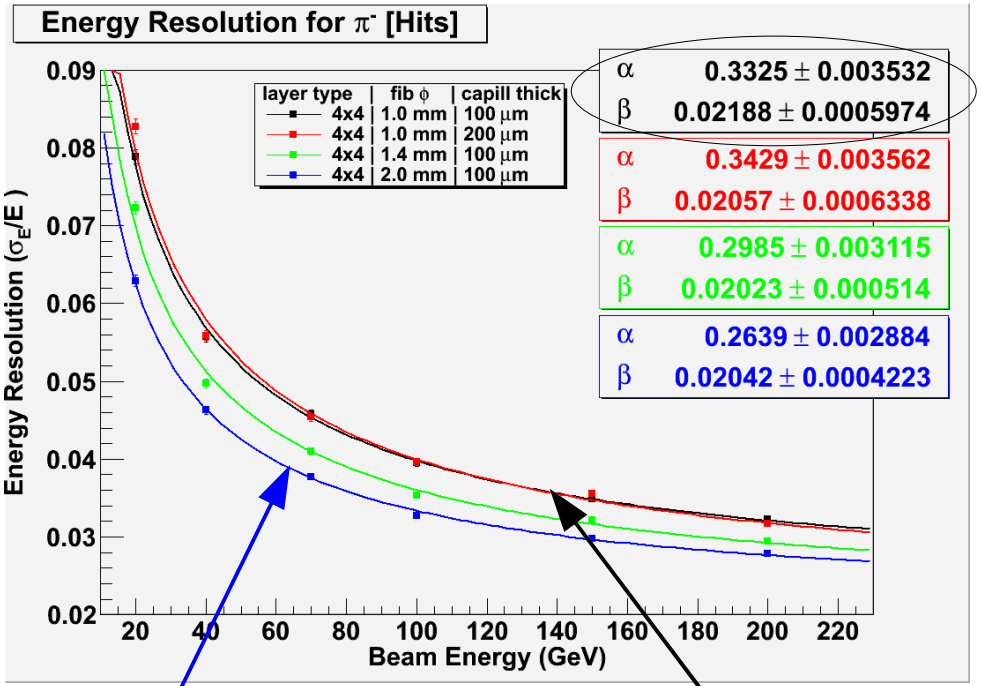


ADRIANO Hadronic Resolution

Pion beams

Dual Readout vs Triple Readout (various fiber layouts)

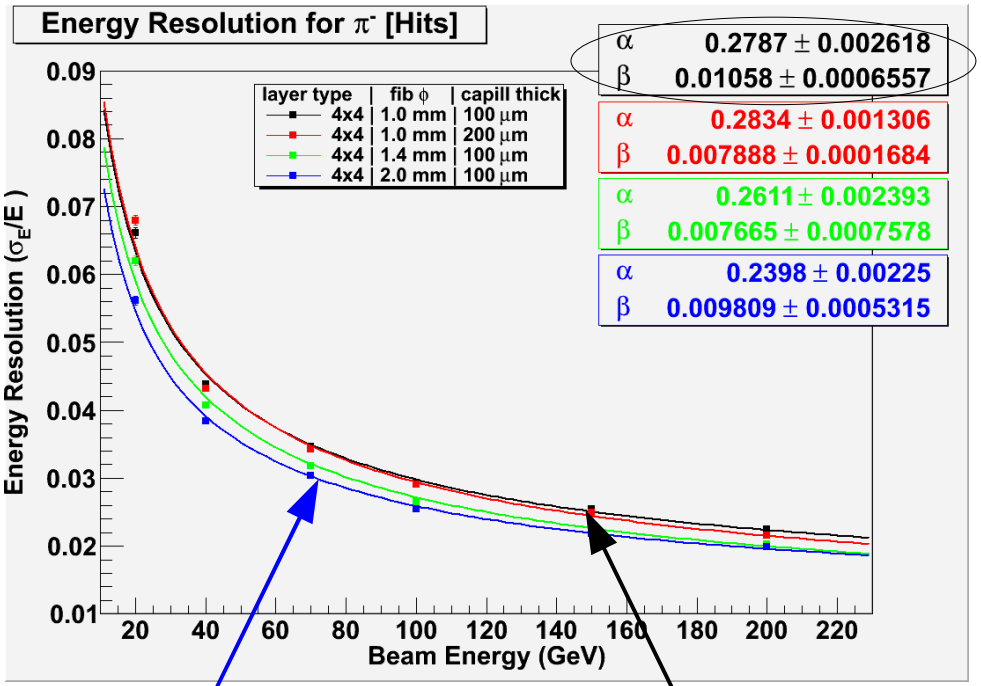
ADRIANO in Dual-readout configuration



$\sigma_E/E = 26\%/\sqrt{E} \oplus 2\%$

$\sigma_E/E = 33\%/\sqrt{E} \oplus 2.2\%$

ADRIANO in Triple-readout configuration



$\sigma_E/E = 24\%/\sqrt{E} \oplus 1\%$

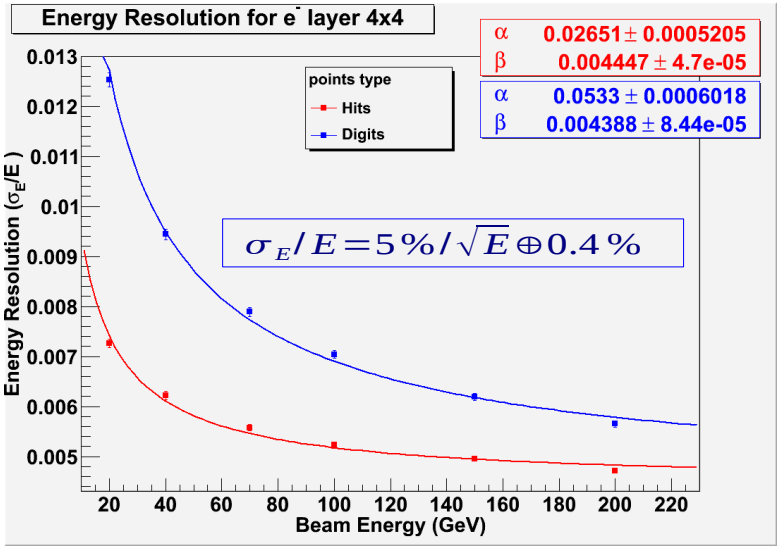
$\sigma_E/E = 28\%/\sqrt{E} \oplus 1\%$

Baseline configuration
Fiber Φ= 1mm
Fiber pitch = 4mm

ADRIANO Resolution for EM Showers (with and without instrumental effects)

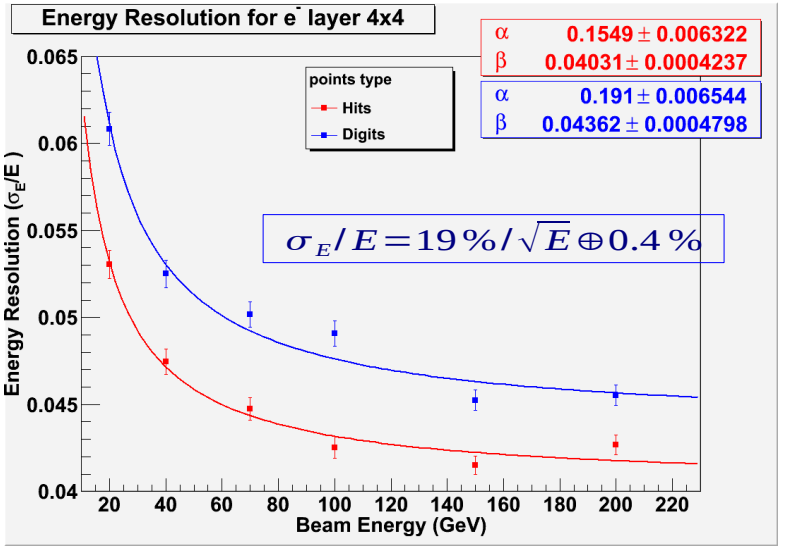
- **Compare standard Dual-readout method vs Cerenkov signal only (after electron-ID)**
- **Blue curve includes instrumental effects. Red curve is for perfect readout**

Use only Cerenkov light



Blue curve includes
- SiPM's ENF
- Constant noise
- Fiber non-uniformity
- 14 bit ADC
- 3pe threshold

Dual-readout (scintillating+Cerenkov)



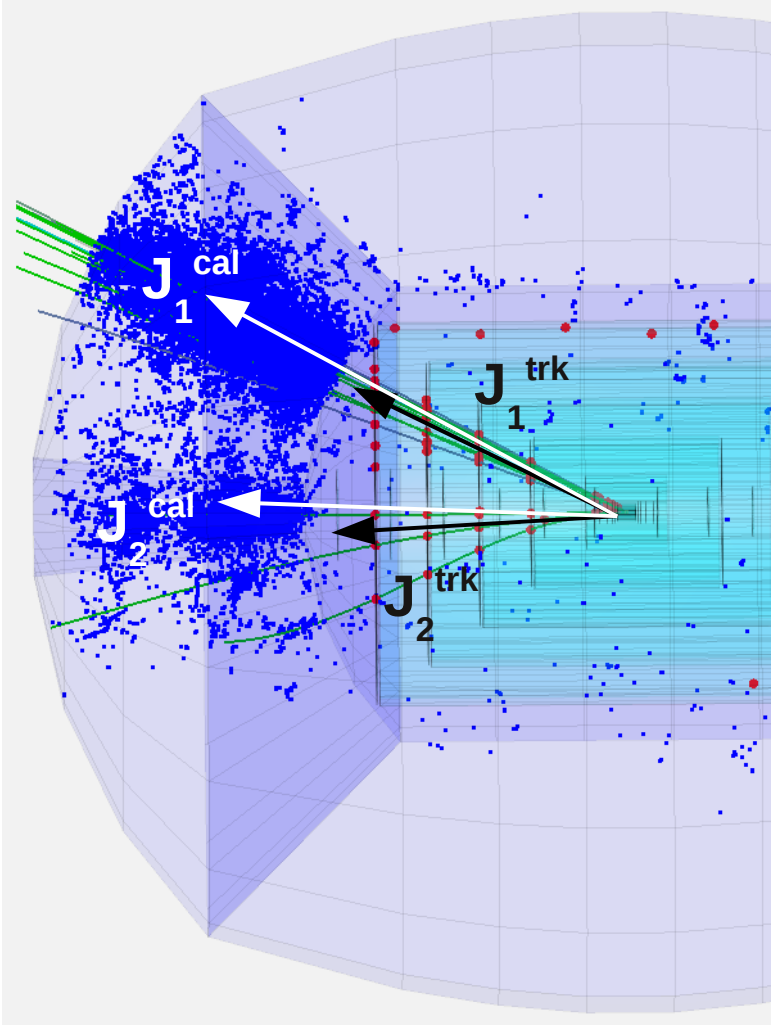
Using Cerenkov signal only for EM showers gives 5%/√E energy resolution while full fledged dual-readout gives only 19%/√E (including instrumental effects)

ADRIANO does not need a front EM section

Jet algorithm strategy

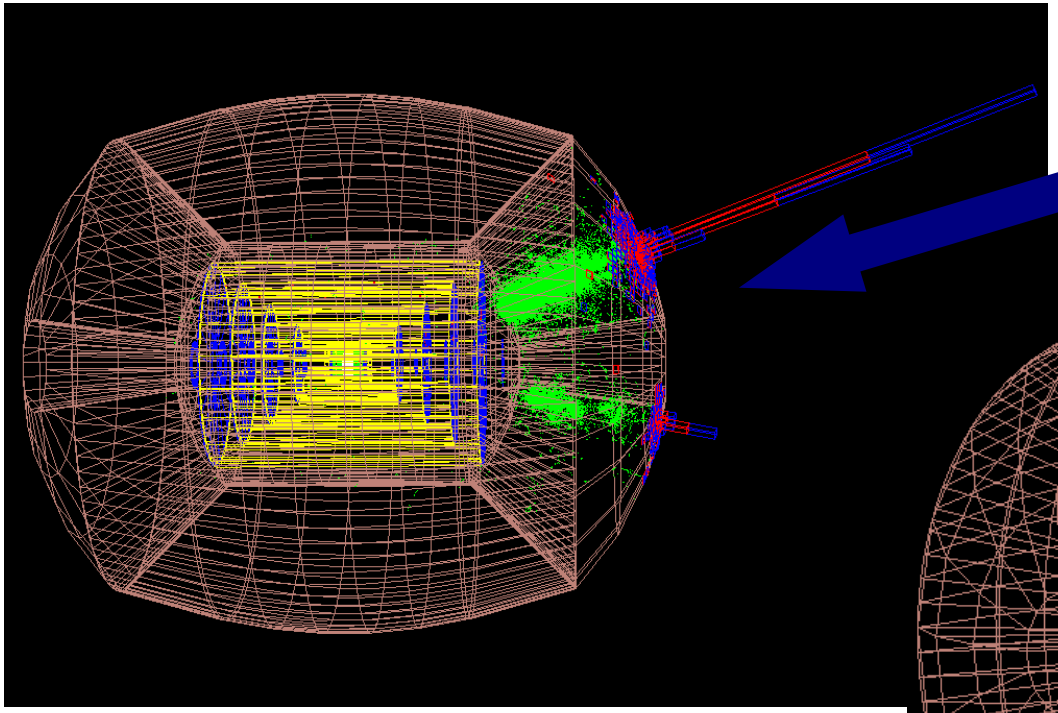
- Assume the jet made of 2 non-overlapping regions
  - **Core**: region of the calorimeter with overlapping showers
  - **Outliers**: hit cells separated from the core
- Measure the **Core energy**
  using information from the calorimeter
- Measure the **Jet axis**
  using information from the tracker detectors
- Reconstruct **Outliers** individually
  using tracking and/or calorimetry
  depending on the charge of the particle

Jet algorithm strategy (continue)

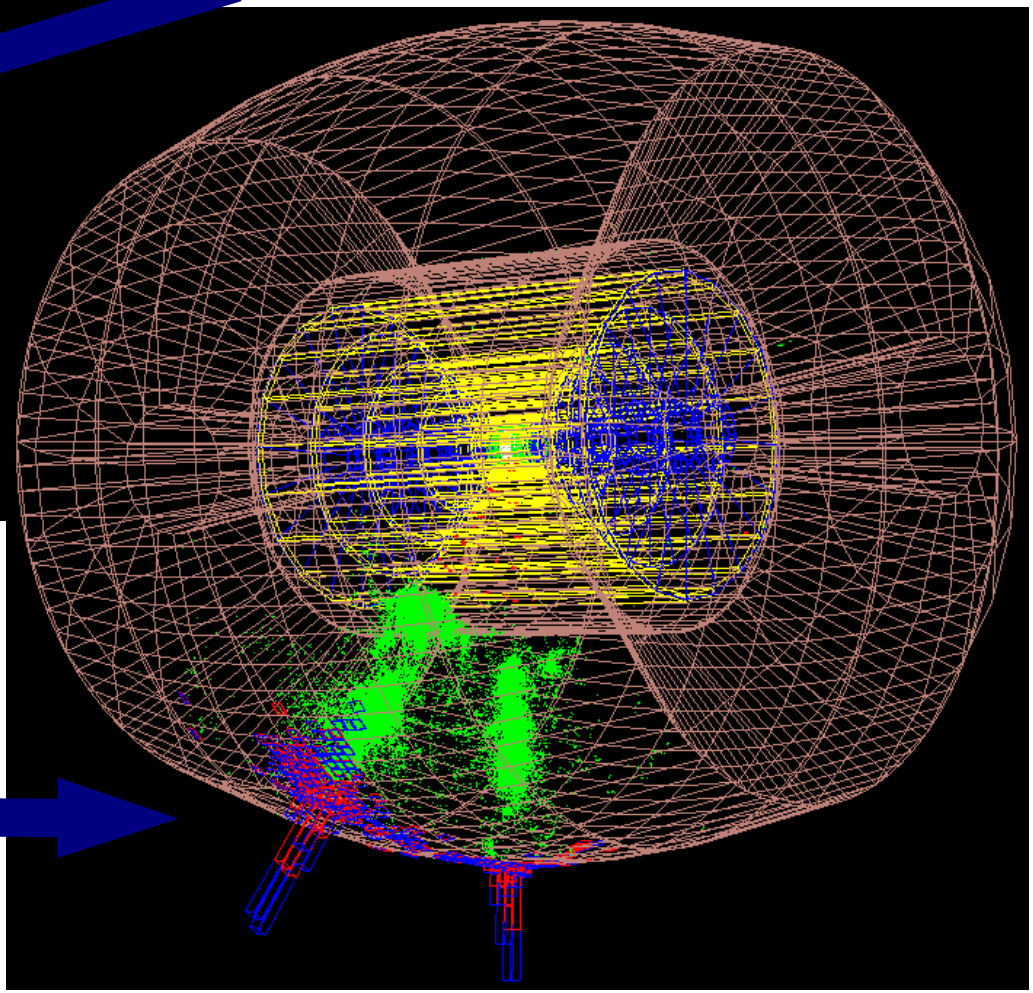


- **Reconstruct Jets using track (J_1^{trk} and J_2^{trk})**
- **Reconstruct Jets using calorimeter towers (J_1^{cal} and J_2^{cal})**
- **Match track and calorimetric Jets**
- **Build Jets using J^{trk} direction and J^{cal} energy**

Some jet event display

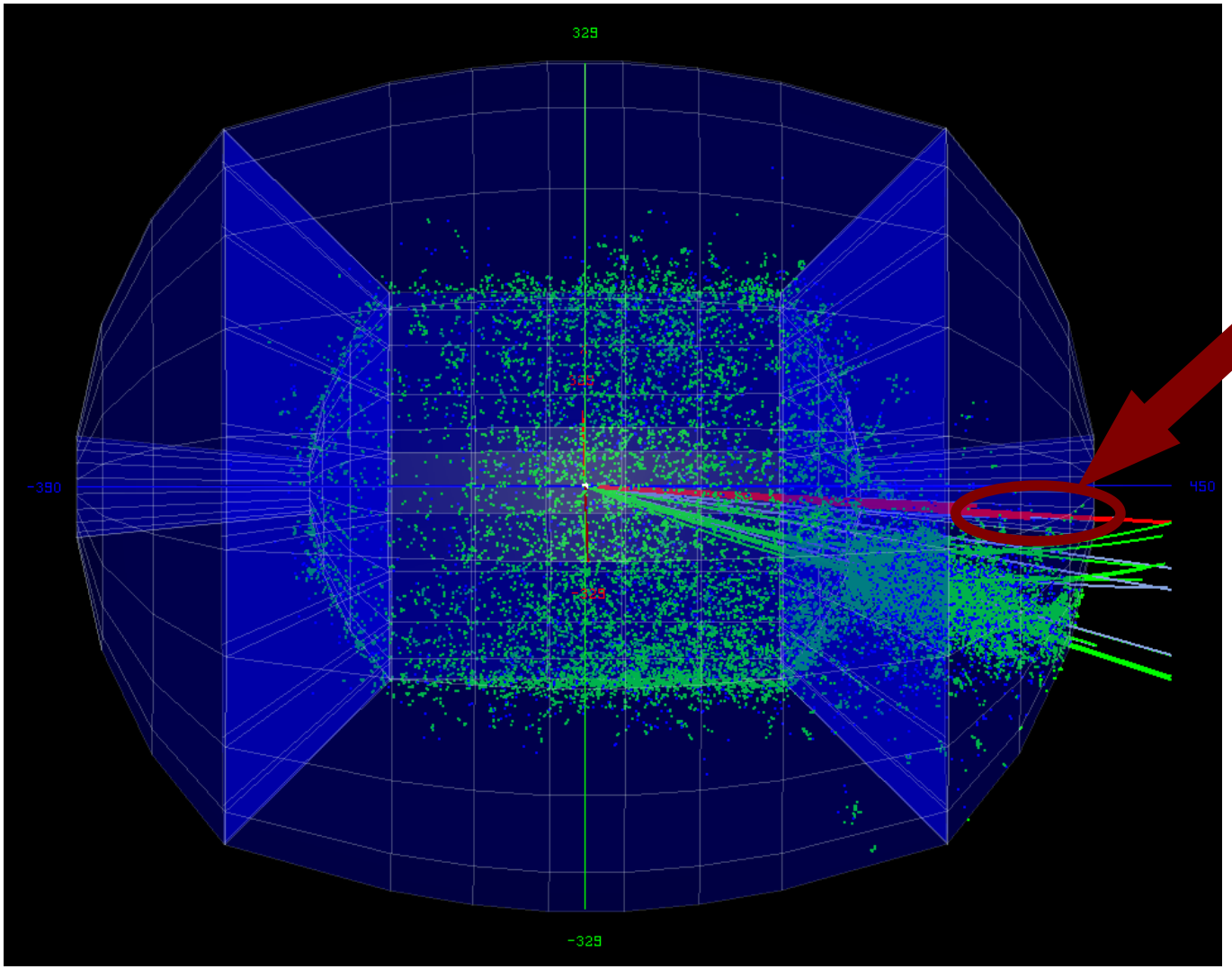


Jets with energy of 435GeV and 68GeV in the endcap



Jets with energy of 234GeV and 117GeV in the barrel

Some jet event display (continue)

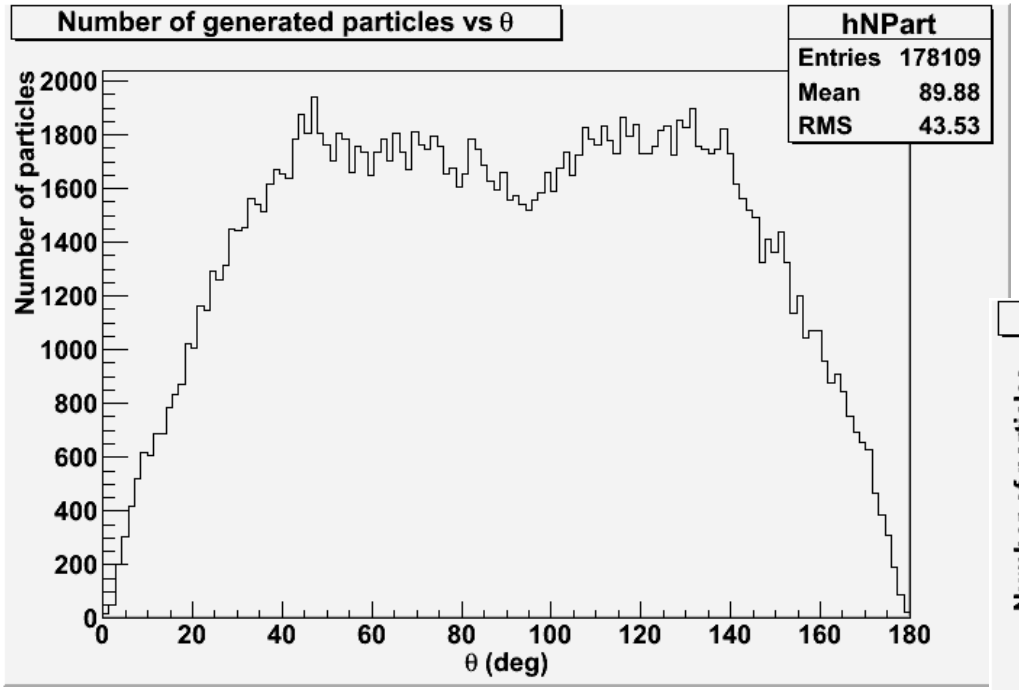


3 π's with ~300GeV of total energy smash the nose

MadGraph Generated particles informations

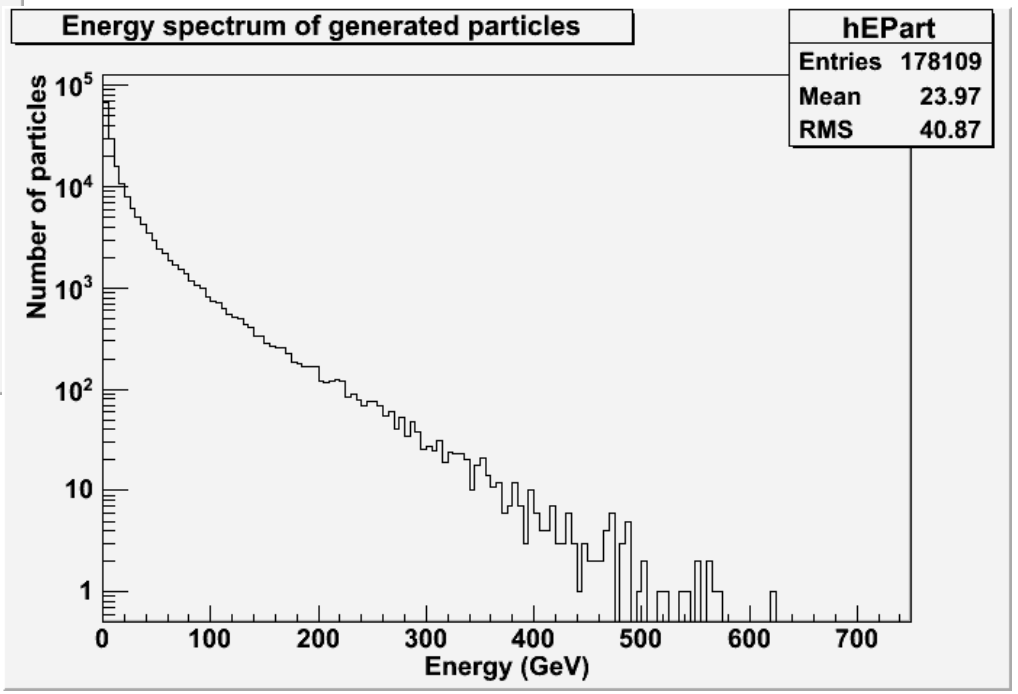
Events generated using MadGraph 4.4.49

http://madgraph.hep.uiuc.edu/

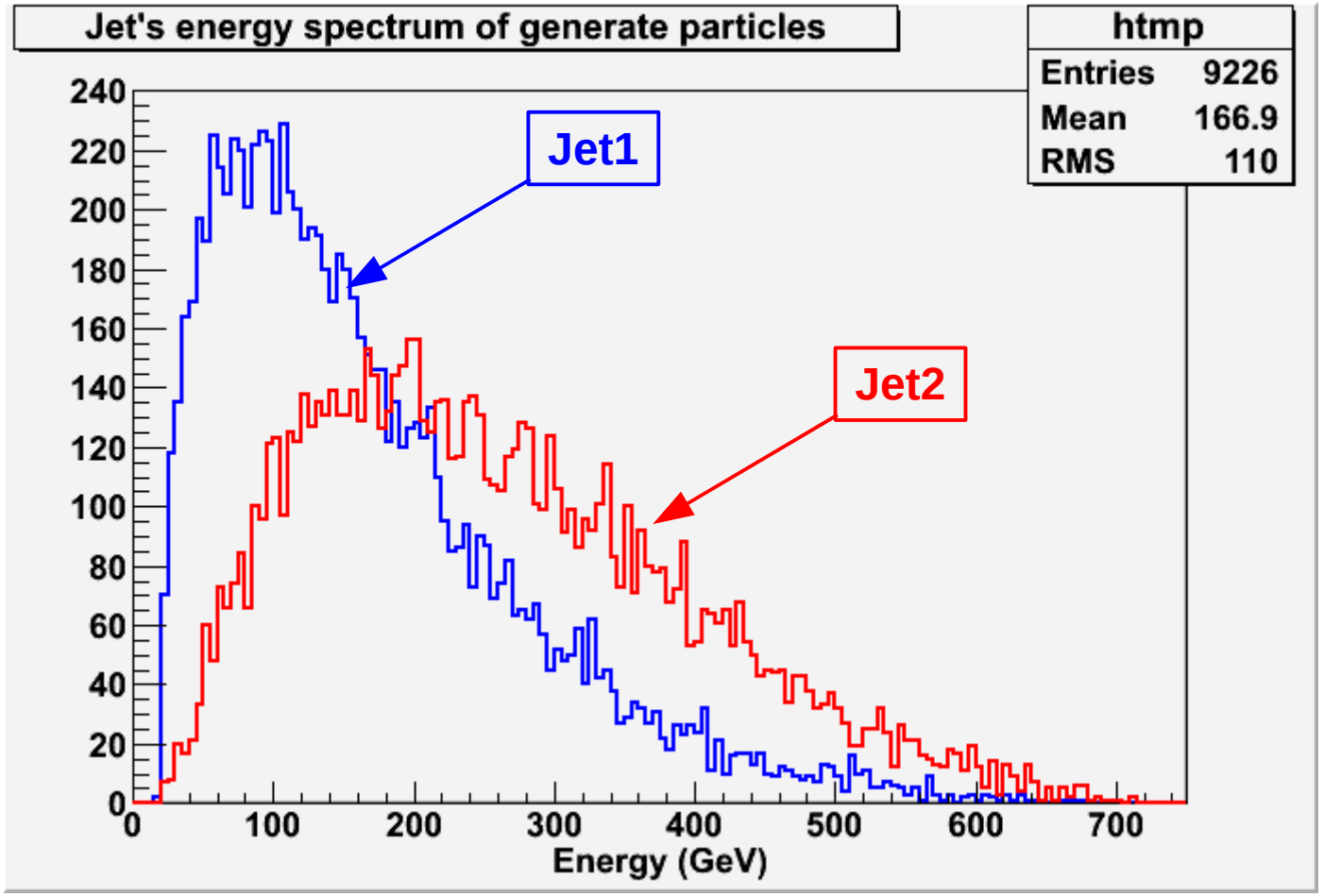


Number of generated particles vs θ (bin = 1.4°)

Energy spectrum of generated particles (bin = 5GeV)



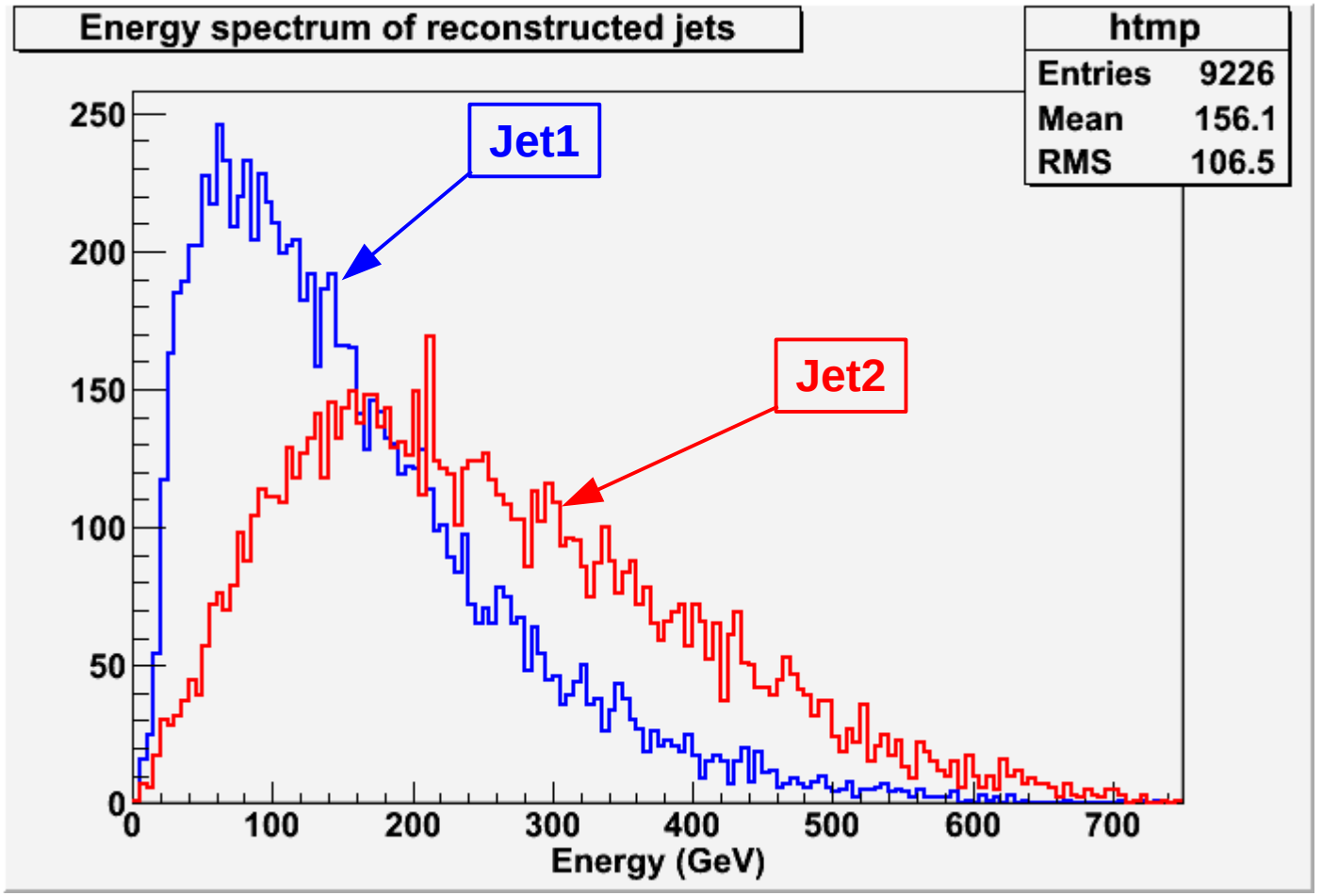
MadGraph Generated particles informations



- **Over 9900 event simulated I found 2 jets in 9226 events**
- **93% jet reconstruction efficiency**
- **Probably in 7% of the events one of the jets smash the nose**

Jet's energy spectrum of generated particles (bin = 5GeV)

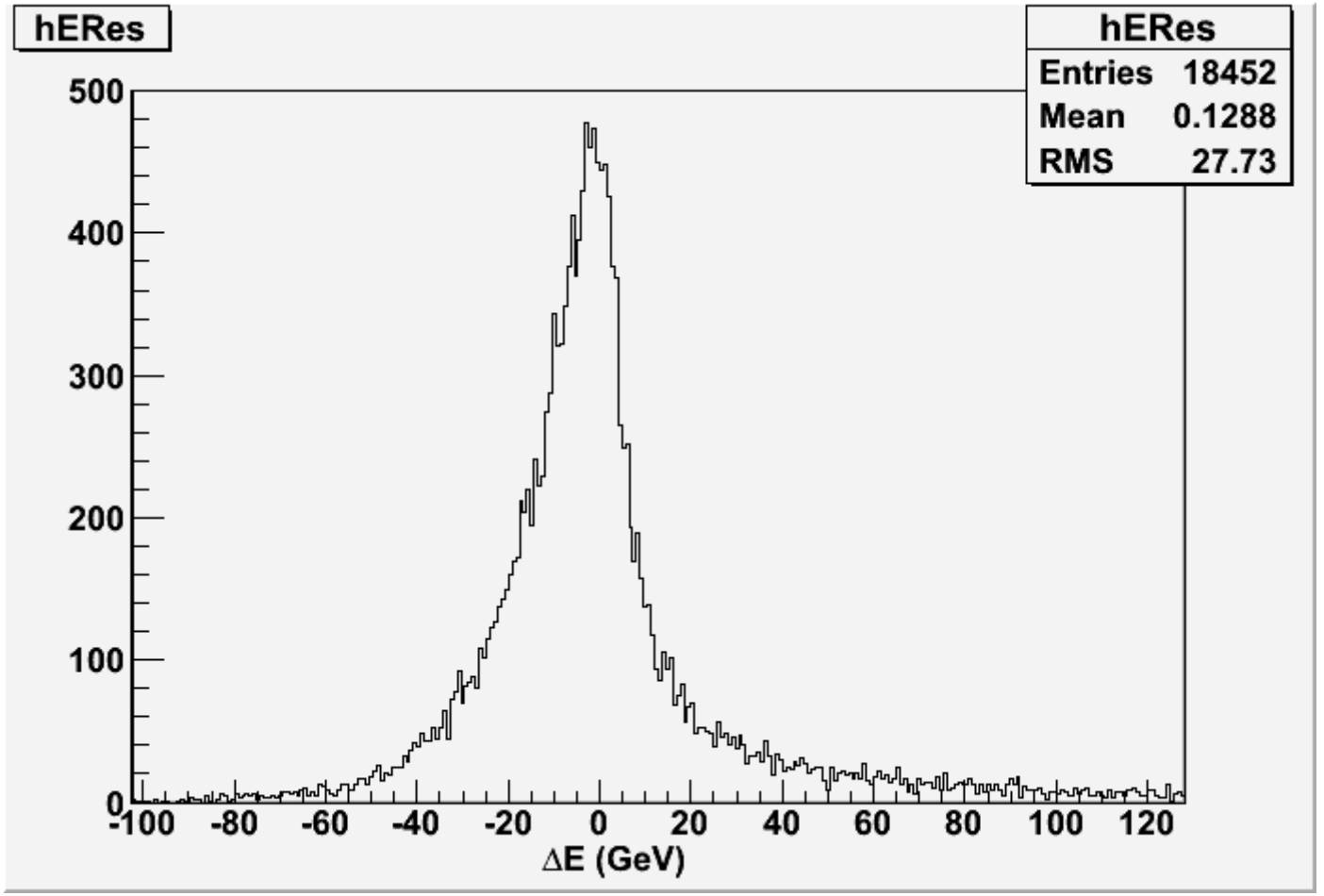
Reconstructed jets energy spectrum



Jet's energy spectrum of reconstructed jets (bin = 5GeV)

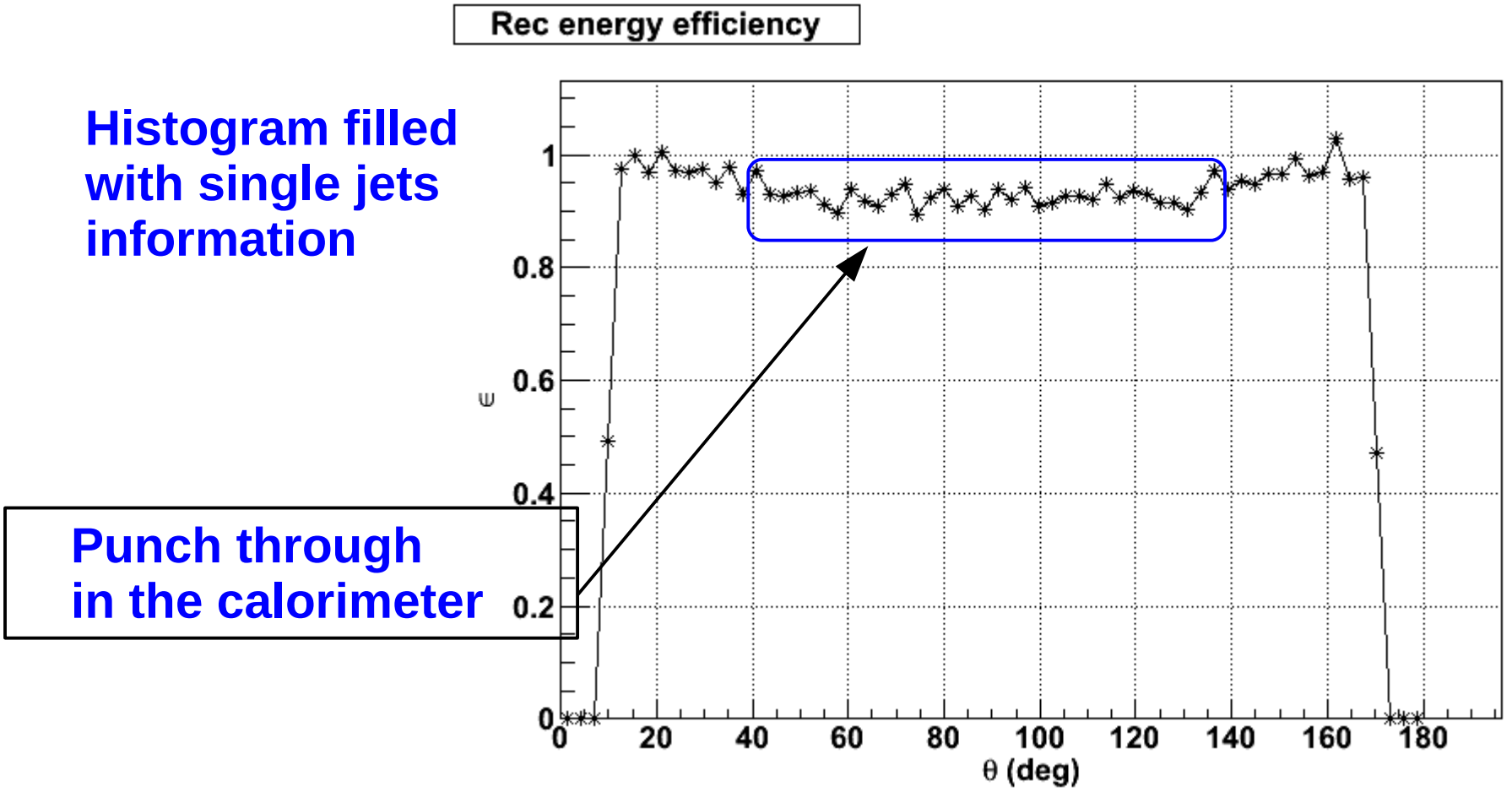
Energy resolution from reconstructed jets

Histogram filled with single jets information



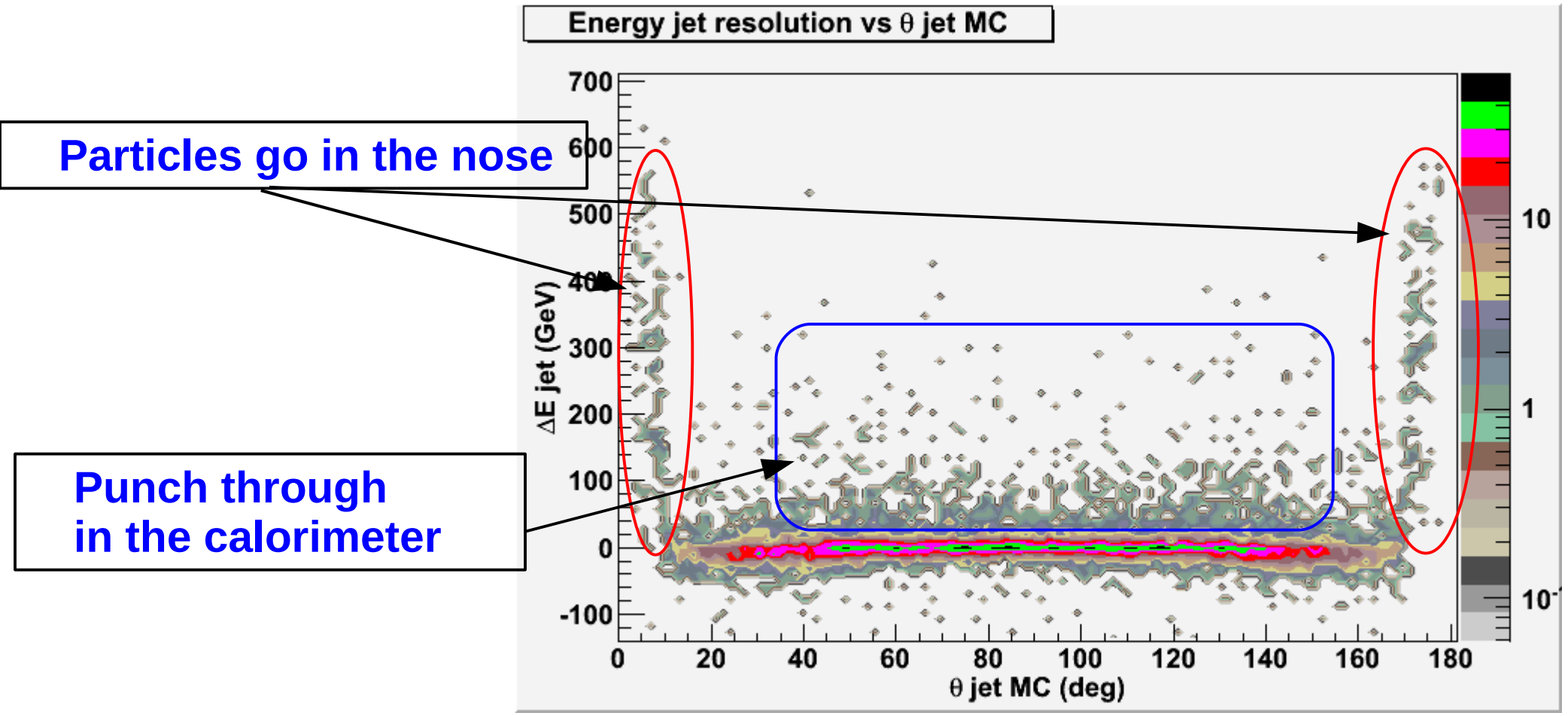
Jet's energy resolution (bin = 1GeV)

Energy efficiency from reconstructed jets



Reconstructed energy efficiency vs theta
drop at ~12° (some particles of the jets go in the nose)

Energy resolution vs theta from reconstructed jets



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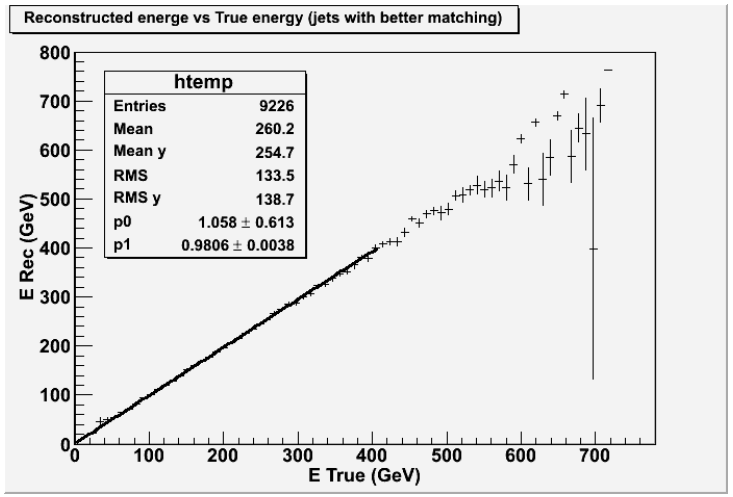
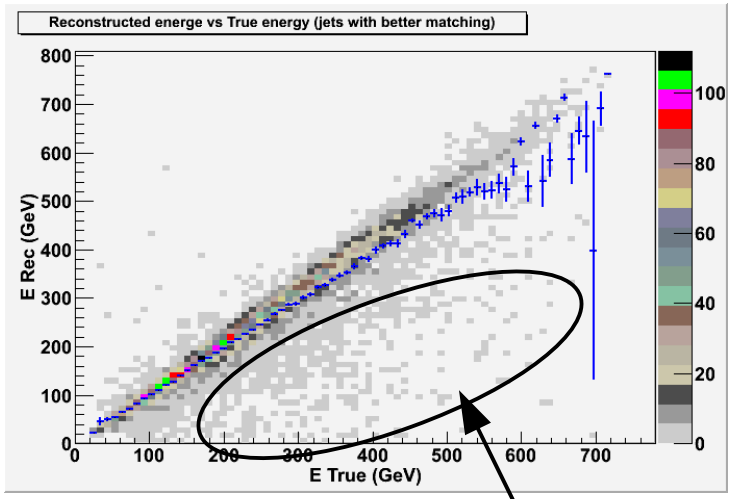
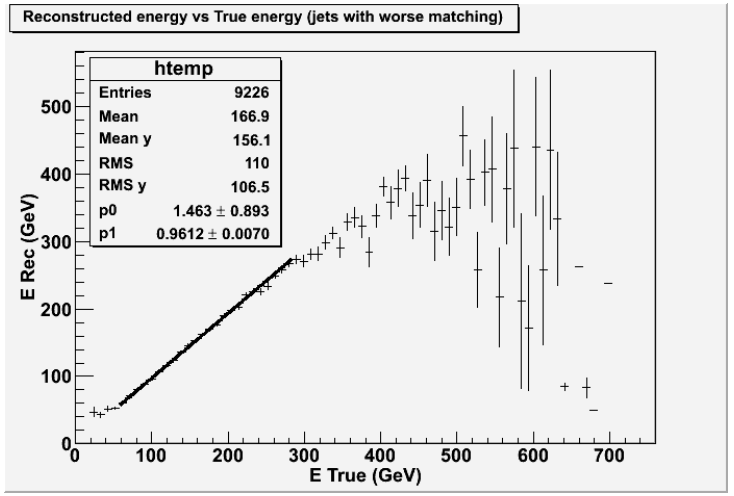
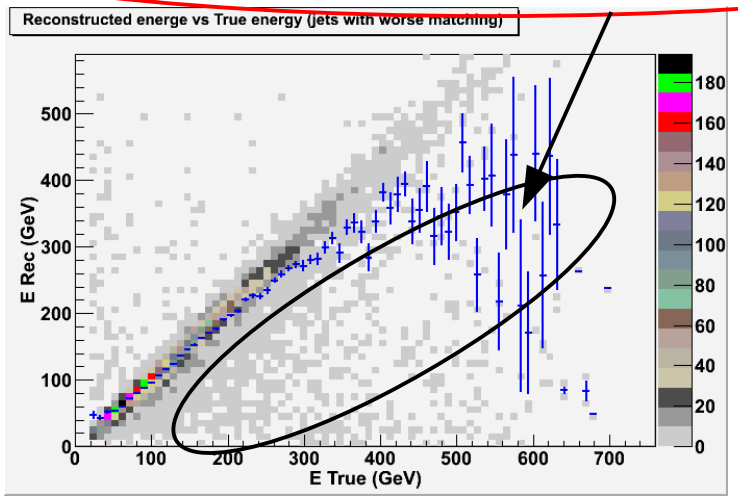
Energy respons from reconstructed jets



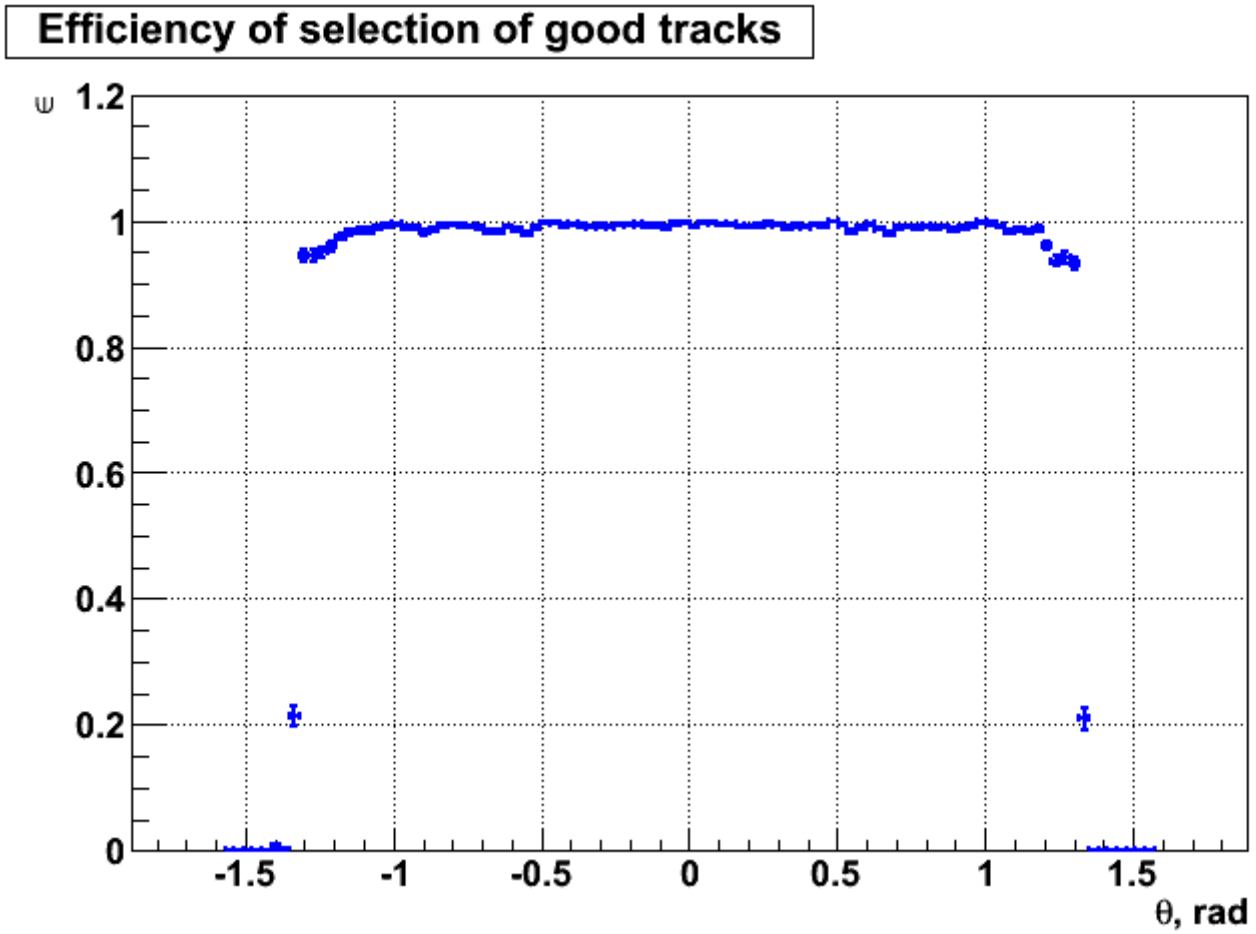


Particles go in the nose or punch through in the calorimeter



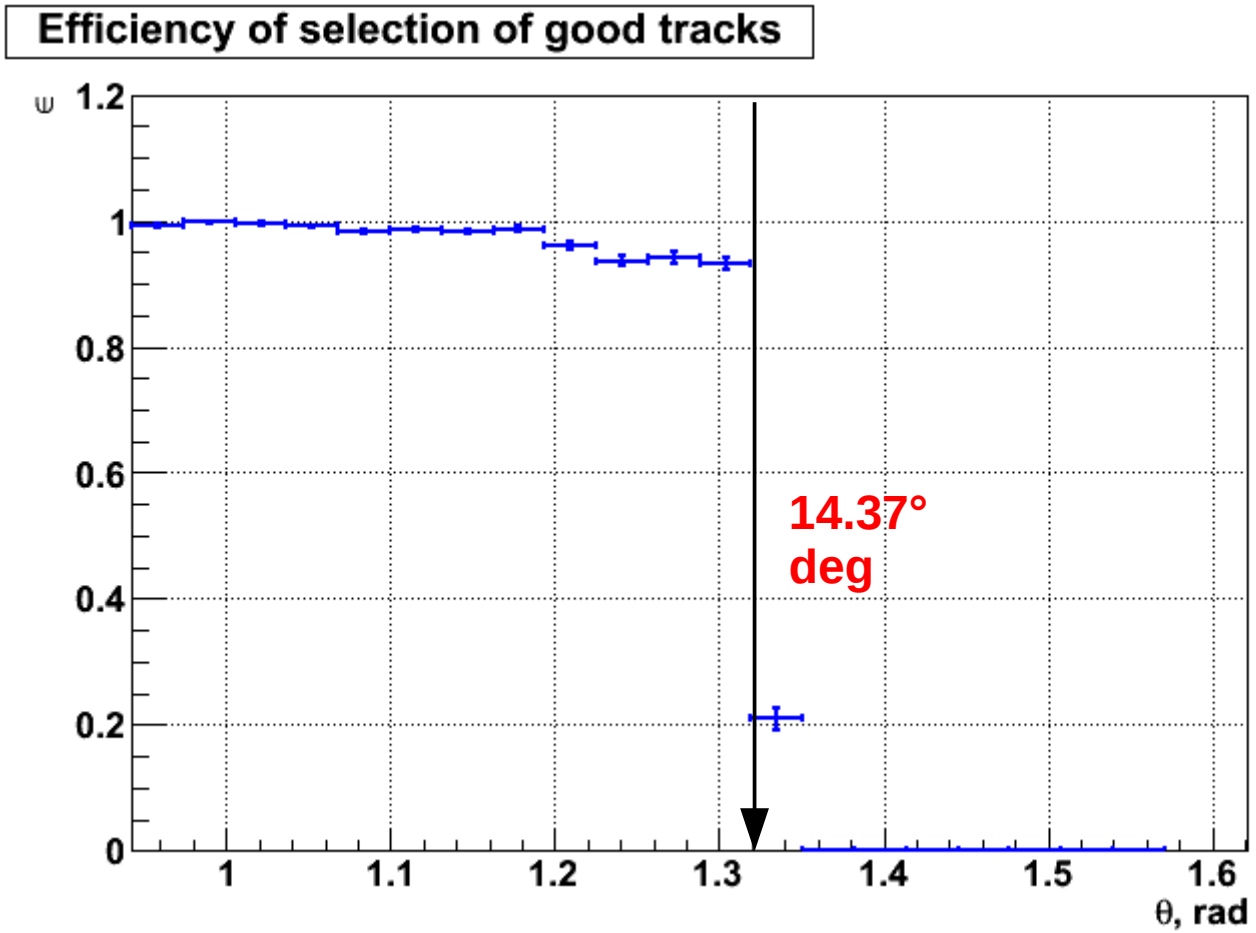


Charged tracks geometrical efficiency



Reconstructed track efficiency vs theta
drop at ~14° (some tracks of the jets go in the nose)

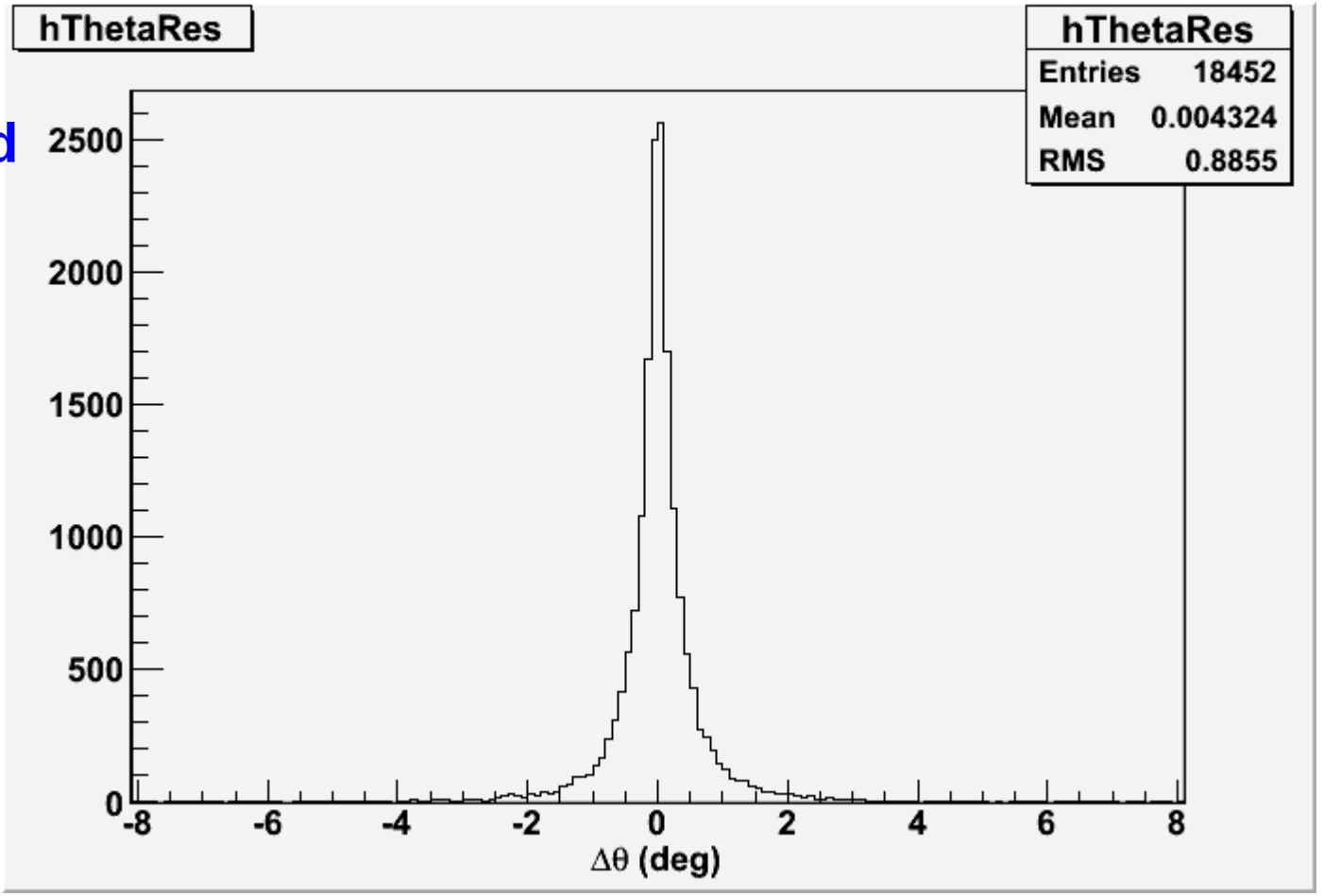
Charged tracks geometrical efficiency zoom



Reconstructed track efficiency vs theta
drop at ~14° (some tracks of the jets go in the nose)

Theta resolution from reconstructed jets

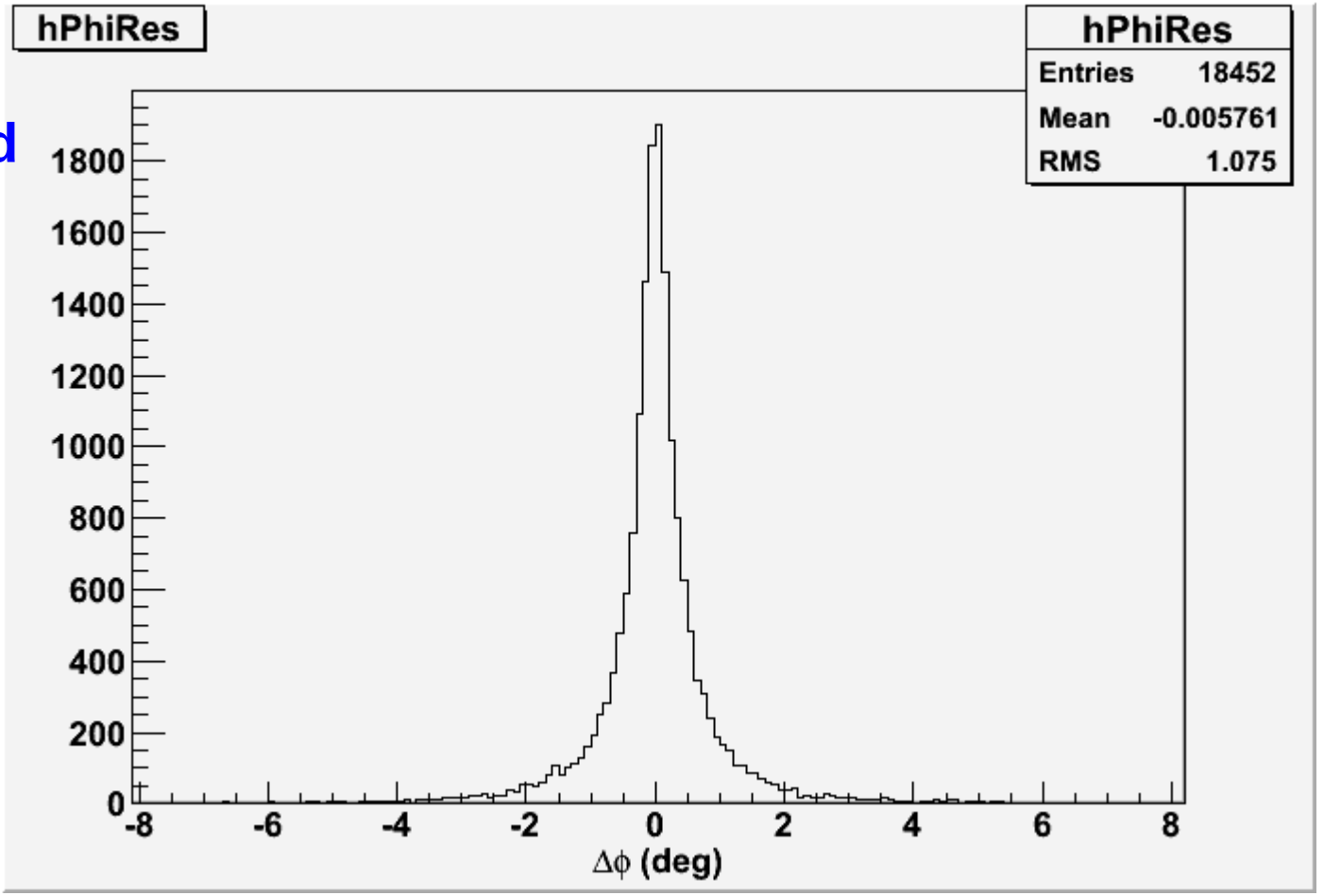
Histogram filled with single jets information



Jet's theta resolution (bin = 0.1°)

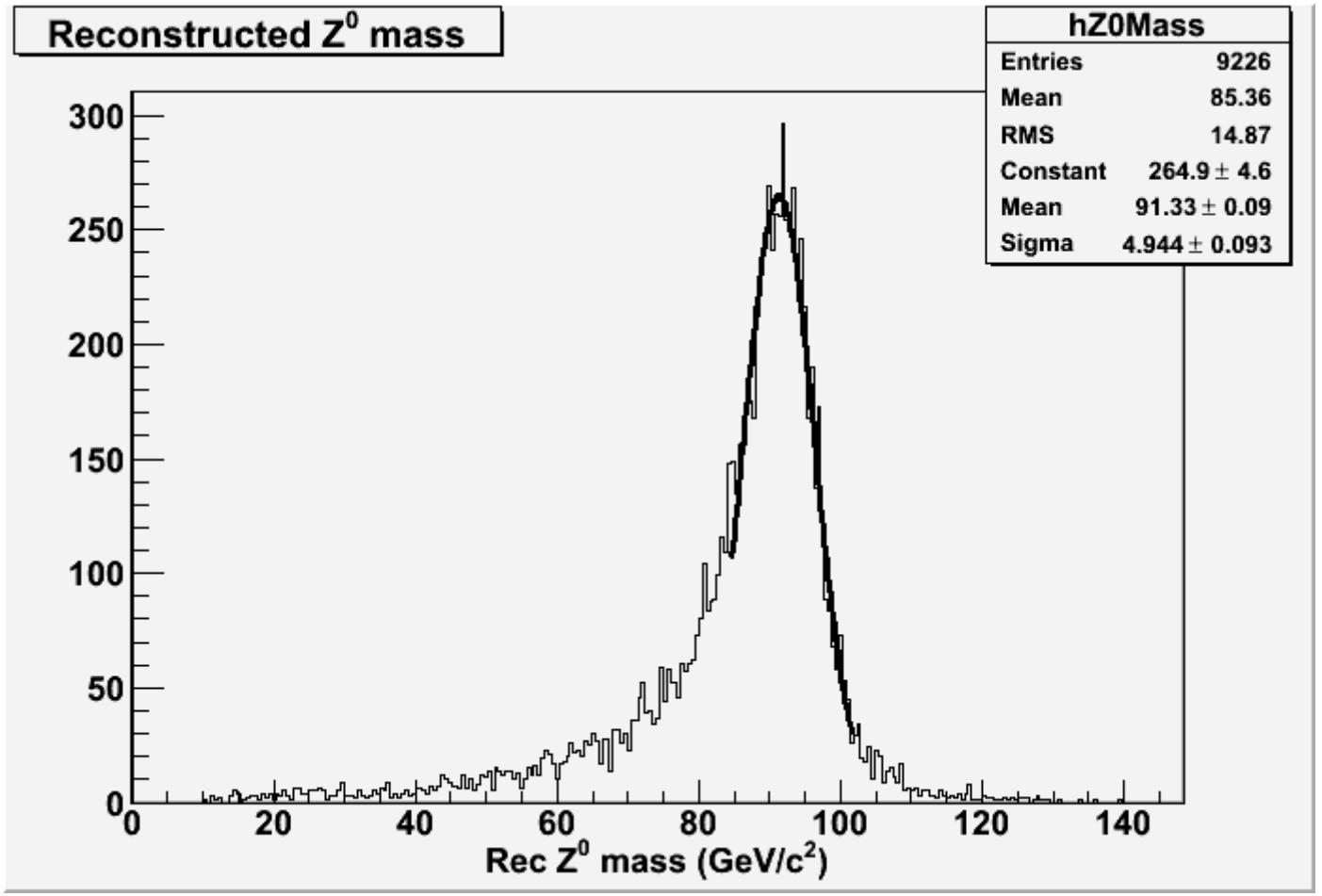
Phi resolution from reconstructed jets

Histogram filled with single jets information



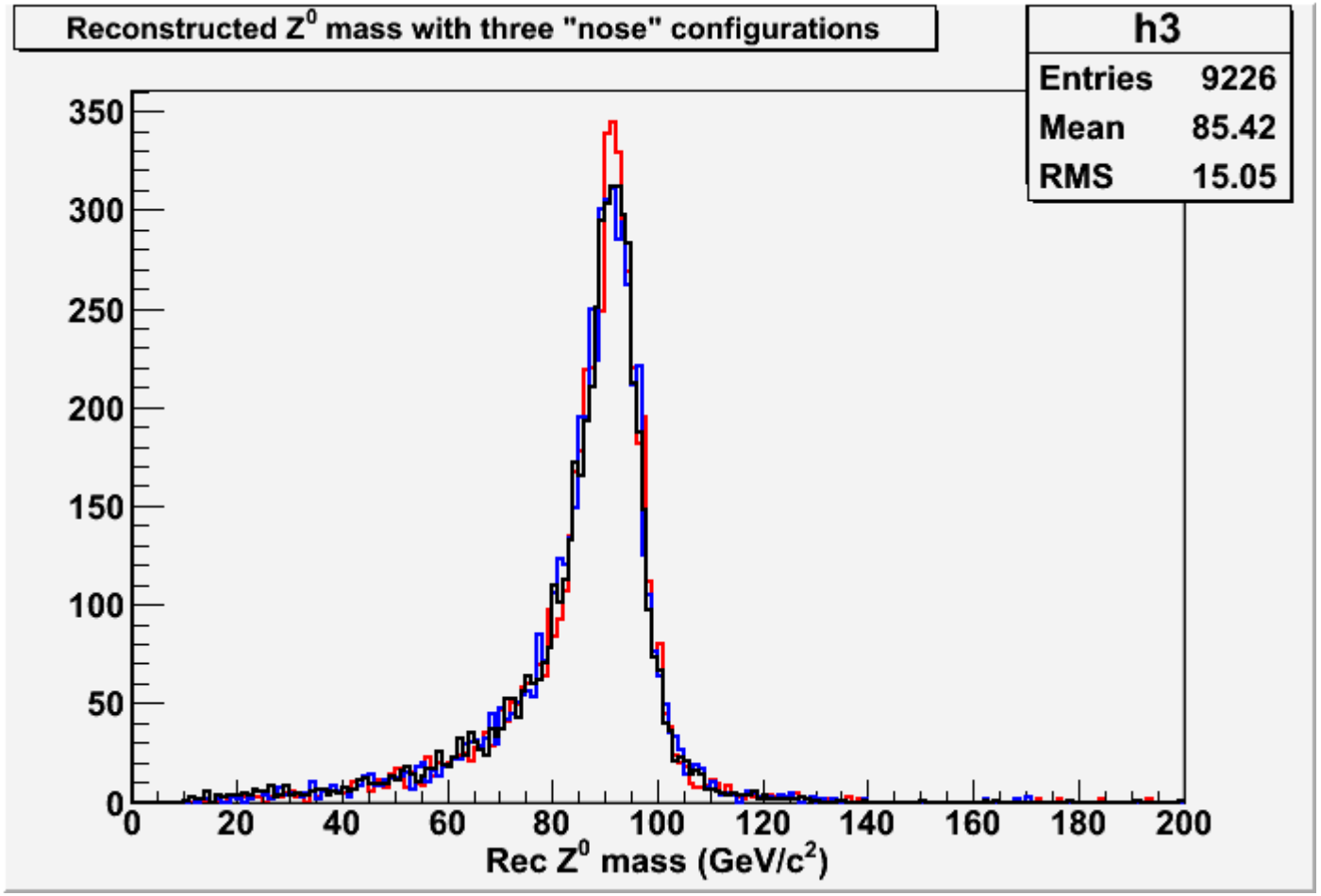
Jet's phi resolution (bin = 0.1°)

Z^0 mass reconstructed



Reconstructed Z^0 mass (bin = 1GeV/c^2)
No cuts applied

Z^0 mass reconstructed with different shienting configuration



Z^0 mass reconstructed with 3 different noses:

- **6° nose**
- **10° - 5° nose w/o overlaps**
- **10° - 5° nose with overlaps**

No significative differences. Just vary geometric efficiency

Reconstructed Z^0 mass (bin = 1GeV/c^2)
No cuts applied

Conclusion

- **Preliminary results have been presented**
- **All the machinery is ready to perform Physics and performances studies**
- **Punch through need to be corrected using a “center of gravity” algorithm.**
- **Need to be added beam background to understand its effect into the detector**

Back-up slides

How Dual Readout works

$$E_{Cal} = \alpha S + \beta C$$

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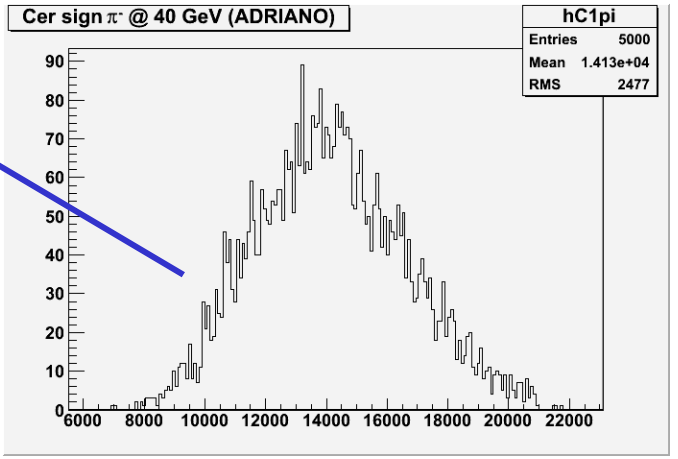
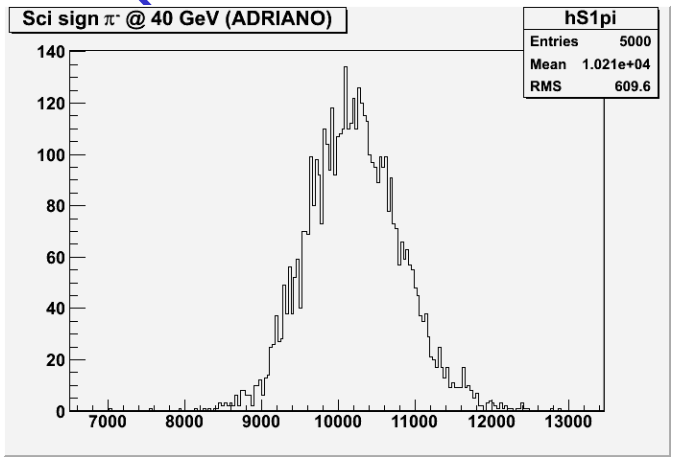
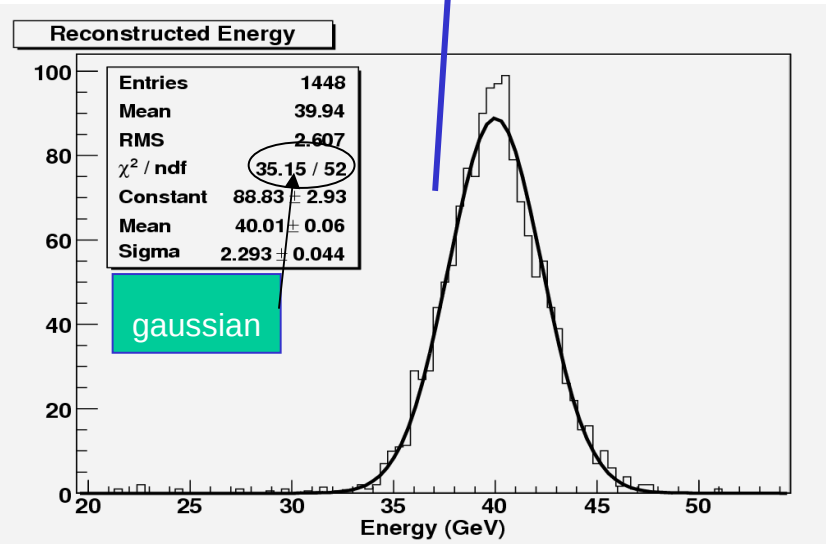
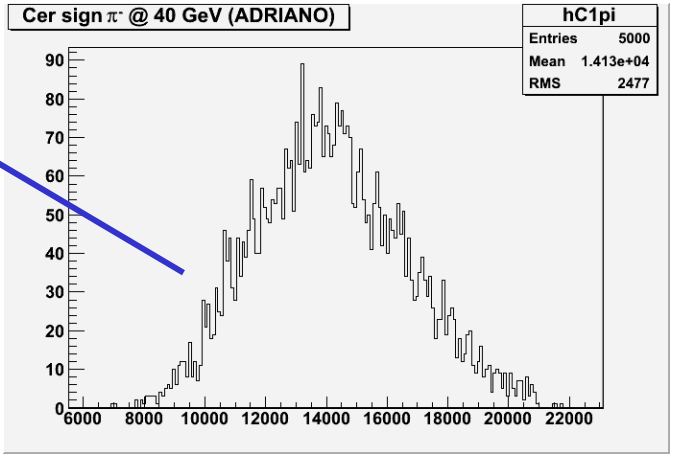


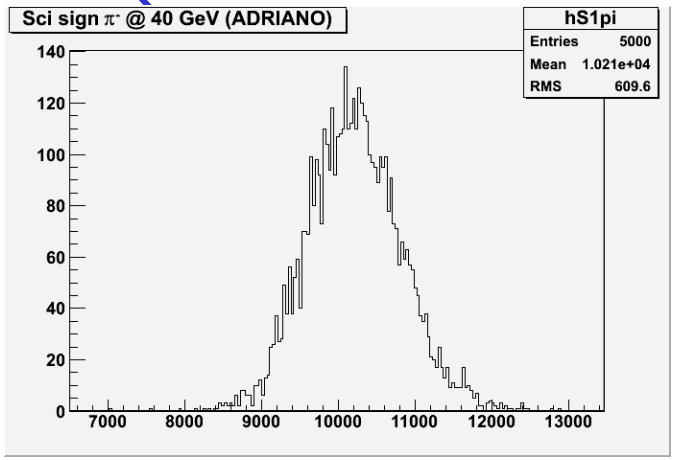


How Dual Readout works

$$E_{Cal} = \alpha S + \beta C$$







Dual Readout -> Triple Readout

$$E_{Cal} = \alpha S + \beta C + \gamma N$$

Separating the neutron signal and use it with different weight improves the energy mesurement